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**Factors contributing to memory of acute pain in older adults undergoing planned and
unplanned hip surgery**

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Abstract

Objectives: Previous research on pain memory provides inconsistent evidence about the accuracy of pain recall, and few studies have attempted to examine broad affective and contextual contributions to this phenomenon. The present research aimed to determine the accuracy of postoperative pain recall after a 3-months, with respect to the context of the surgery and the congruence of affective states concurrent with the initial experience and its recall. The study also aimed to identify predictors of remembered pain by analysing a range of sensory, cognitive and affective factors.

Methods: Older adults, undergoing planned ($N = 40$) and unplanned hip surgery ($N = 31$), were enrolled in this prospective study to investigate their pre-, post-surgery, and delayed ratings of expected, experienced, and recalled pain intensity and unpleasantness, state anxiety and positive and negative affect.

Results: Memory of postoperative pain was found to be accurate, regardless of the context of the surgery. Affective states in the postoperative period were congruent with those during pain recall. The study also revealed that in planned surgery context, remembered pain was predicted by experienced postoperative pain, cognitive functions, positive and negative affect; whereas in unplanned surgery context its significant predictors included age, anxiety, negative and positive affect.

Discussion: This study suggests that older orthopaedic patients remember postoperative pain correctly after 3 months and that mood dependence effect may contribute to memory of pain. Pain recall after planned surgery appears to depend mainly on the actual experience, while following unplanned surgery it depends on affective factors. Present findings contribute to scarce knowledge about pain memory in older adults and have implications for patients' recovery and best practice in perioperative hospital care.

1. Introduction

Retrospective evaluations of pain not only serve as the basis for medical diagnoses, choice of treatment, and proof of symptom improvement, but they also may affect subsequent pain experience^{1,2} and the willingness to return for painful procedures,³ and they may even contribute to the development of chronic pain.^{4,5} Importantly, there is growing evidence of distortions in the memory of pain. Numerous studies have found that recalled acute pain can be overestimated^{6–10} or underestimated.^{6,11–14} In contrast, some research has reported that recall of acute pain is accurate.^{6,10,13,15–19} The findings vary across different types of pain; for example, the memory of chronic and experimental pain tends to be overestimated^{1,2,20,21} or accurate.^{22–24} Several studies also indicate that pain may be remembered correctly after short delays, but its recalled intensity becomes exaggerated with time.^{10,20,21} It further has been suggested that a number of factors other than the type of pain and the time of recall can influence the memory of pain, including its actual intensity,^{6,9,11–13,15,21} its expected intensity,^{9,18,19,25} and affective variables. Emotional states accompanying painful experience, in form of anxiety,^{2,6,7,9,12,14–16} negative affect^{1,6,11,15,21} and positive affect,^{6,12,15,16} have been repeatedly identified as predictors of pain recall.

These combined findings illustrate the role of various psychological factors in the memory of pain. However, an additional mechanism, which possibly accounts for the inconsistencies in the existing pain memory research, has been implicated in broader studies of memory – i.e., mood dependent memory. Mood dependent memory²⁶ occurs when the congruence between affective states at encoding and retrieval facilitates memory. This effect should be distinguished from the mood congruence effect,²⁷ which describes how positive memories are better recalled in a positive affective state, whereas the likelihood of recalling negative events increases in a negative mood state. The concept of mood dependent memory can be easily applied to pain studies, such that the congruence of emotional states during the actual pain

experience and delayed pain recall would facilitate the accuracy of pain memory, whereas the incongruence of affective states between those two points in time would hinder accurate pain recall, resulting in its under- or overestimation. Thus, the first aim of this study is to test the accuracy of pain memory after a 3-month delay, while controlling for mood congruence.

Furthermore, recent research has recognized the context of a painful experience as another potential factor affecting the way pain is remembered. Severe, acute pain accompanying positively valued events, such as childbirth, has been found to be underestimated at recall, whereas similar pain experienced in the markedly negative context of gynecological surgery has been overestimated at recall.⁶ Coupled with the evidence of the effect of positive affect on pain memory,^{6,12,15,16} such effects could be attributable to the positive emotional valence of certain painful events. On these grounds, it can be hypothesized that the underestimation effect would occur in the context of elective hip surgery – a desirable and longed-for event to achieve pain relief and functional improvement, whereas pain overestimation would occur in the context of emergency hip surgery, which is characterized by negative emotional framing due to sudden, unexpected trauma and functional decline.²⁸ The present study's second aim is to test these predictions by examining the memory of orthopedic pain (which previously has been only assessed after very short delays)¹³ with respect to the context of the operation.

The third and final purpose of this study is to establish predictors of recalled pain intensity and unpleasantness by comprehensively investigating the contributions of prospectively measured, expected and experienced pain, positive and negative affect and anxiety to the memory of pain. Because the study employed a population of older adults, in which these research questions have not been previously investigated, age and level of cognitive functioning were considered to be, among others, potential factors influencing pain memory, as they have been previously suggested to alter reports of experienced pain.^{29–31}

2. Materials and Methods

2.1. Participants

Study participants were recruited during their stay on the orthopedic wards in Kraków, Poland. A total of 71 patients who fulfilled the following inclusion criteria participated in the study: awaiting hip surgery, age ≥ 60 , ability to maintain logical verbal contact and Mini Mental State Examination (MMSE) score ≥ 19 . Depending on the context of the operation, patients were allocated to two groups: 40 of them underwent planned surgery (PS) and 31 underwent unplanned surgery (US). The baseline characteristics of the participants are presented in Table 1. The surgical procedure in the PS group involved total hip arthroplasty or hemiarthroplasty, in which a hip joint affected by degenerative osteoarthritis (coxarthrosis) was replaced with a prosthetic implant. The reason for surgery in the US group was a femoral (neck or pertrochanteric) fracture. Patients with a femoral neck fracture underwent hip replacement surgery, whereas the pertrochanteric fracture surgery entailed a procedure consisting of closed reduction of the fracture by internal fixation with a dynamic hip screw or a gamma nail. Both types of surgeries were conducted under either general or spinal anesthesia.

2.2. Materials

Level of cognitive functioning was measured with a commonly used screening test, the Mini-Mental State Examination (MMSE),³² which assesses functions such as orientation in time and place, attention, memory, language and visual-motor skills. A score of 19 of 30 points, which corresponds to the lower range of mild dementia, was adopted as a cut-off point to qualify for the study, because such a level of cognitive functioning is considered to be sufficient for comprehending instructions and making accurate self-assessments of pain.^{33,34}

The participants rated their maximum intensity and unpleasantness of expected, experienced, and recalled pain, as well as their state anxiety, on an 11-point Numeric Rating Scale (NRS), which has been recommended as the best tool to measure postoperative pain

intensity among older adults.³⁵ The exact wording of the instructions to rate maximum pain was based on the ‘peak-end rule’,¹⁰ which states that pain intensity at the worst and the final moment of a painful experience determines its memory. Furthermore, especially in terms of postoperative pain, maximum pain ratings were preferred over average pain ratings, considering relatively wide time window between the surgery itself and the second phase of data collection (up to 48 hours), that also included the time needed for anesthesia to subside. In view of constant changes in pain intensity and unpleasantness during that period and the possible occurrence of memory distortions, maximum pain ratings were considered the most adequate. Maximum pain intensity was rated from 0 = ‘no pain’ to 10 = ‘the most intense pain imaginable’; maximum pain unpleasantness was rated from 0 = ‘not unpleasant’ to 10 = ‘the most unpleasant pain imaginable’; and anxiety was rated from 0 = ‘no anxiety’ to 10 = ‘the most intense anxiety imaginable’.

Finally, positive and negative affective states were measured by the two 10-item mood scales comprising the Positive and Negative Affect Schedule (PANAS).³⁶ Positive affect scale measures the extent to which the participants feel enthusiastic, active and alert. Negative affect scale reflects subjective distress and unpleasant engagement. Low positive affect and high negative affect are considered main features of depression and anxiety. Although validated measures of depression (Beck Depression Inventory) and anxiety (STAI State Anxiety Scale) showed moderate positive correlations with PANAS negative affect scale and modest negative correlations with PANAS positive affect scale,³⁶ the coefficients are too low to indicate interchangeability of these measures. In contrast to the aforementioned measures of unpleasant mood states, PANAS allows assessing two distinctive affect dimensions separately. Further advantage of PANAS is that it allows measuring both negative and positive affect as current affective state, that is mood experienced at the time of testing (unlike depression scales that assess mood over a longer period of time, e.g., the past week), in line

with the aims of the present study. Respondents rated the extent to which they experienced particular positive and negative emotions (e.g., ‘alert’, ‘distressed’, ‘excited’, ‘nervous’) on a 5-point scale: 1 = ‘very slightly or not at all’, 2 = ‘a little’, 3 = ‘moderately’, 4 = ‘quite a bit’ and 5 = ‘very much’. The positive and negative affect scales have been shown to be highly internally consistent ($\alpha = 0.84 - 0.90$), largely uncorrelated ($r = -0.12 - -0.23$), and stable at appropriate levels over 2-months period ($r = 0.39 - 0.71$).³⁶

2.3. Design and procedures

The study consisted of three phases, and the participants were not informed that the last phase would investigate their memory of pain. The first phase (T1) began when the patients agreed to participate in the study, 24 to 48 hours before undergoing surgery. After conducting the MMSE, participants were asked to rate their experienced pain intensity, pain unpleasantness, and anxiety on a NRS, and their experienced positive and negative affect on the PANAS, as well as the maximum pain intensity and unpleasantness expected after the surgery on a NRS.

The second phase of the study (T2) was conducted between 24 and 48 hours after the surgery. At that time, participants rated their experienced maximum post-operative pain intensity, pain unpleasantness and anxiety on the respective NRS, as well as their experienced positive and negative affect on the PANAS.

A telephone interview was conducted with each participant about 3 months after the surgery. According to studies of acute pain recall, potential memory distortions are often revealed only after several weeks,^{6,8-10,25} and extending the delay period beyond 3 months does not alter the memory of pain.^{6,11,15,16} Therefore, the length of the delay in the present study was set at approximately 3 months. During the third phase (T3), participants were asked to recall and rate the maximum post-operative pain intensity and unpleasantness on the respective NRS, and were instructed to rate and describe *how they remembered* the pain

experienced in the second phase of the study, rather than to *recall how they had rated* the pain after the surgery. Pain intensity and unpleasantness, anxiety, and positive and negative affect experienced at the moment of recall were also measured.

The protocol for this study was approved by the Research Ethics Committee of the Institute of Psychology of the Jagiellonian University. All participants provided informed written consent.

2.4. Statistical analyses

All the analyses were conducted using the STATISTICA data analysis software system, version 12 (Statsoft Inc., Tulsa, OK, USA). The level of significance was set at $p < 0.05$ for rejecting the null hypothesis in all the statistical analyses. Additionally, compromise power analyses were performed using G*Power 3.1.9.2.^{37,38}

In order to determine whether there were any inter-group differences in baseline characteristics, *t*-tests were conducted for continuous variables (age, MMSE), and *chi*² tests were conducted for nominal variables (gender, type of surgery, type of anesthesia). Pearson's correlation coefficients (*r*) were calculated to examine relationships between recalled pain intensity and unpleasantness, and age and MMSE.

Statistical comparisons were performed using a repeated-measures analysis of covariance (ANCOVA) design, with the context of the surgery (planned vs. unplanned), type of surgery (hip replacement vs. internal fixation) and gender (male vs. female) as between-subject factors, and time of rating (experienced vs. recalled for pain, and T2 vs. T3 for affect) as a within-subject factor. Age and MMSE were the covariates. Separate ANCOVAs were conducted for each dependent variable: pain intensity, pain unpleasantness, positive affect, and negative affect.

In order to test the accuracy of pain recall and mood congruence, the *F*-tests were followed by planned comparisons on experienced (T2) versus recalled (T3) measures of pain intensity

and pain unpleasantness, and also on T2 versus T3 measures of positive affect and negative affect. Separate analyses were conducted for the PS group and the US group.

Stepwise forward multiple regression was performed to determine the degree to which pain memory was predicted by age, MMSE, expected pain intensity and unpleasantness, experienced pain intensity and unpleasantness at T1, T2, and T3, anxiety at T1, T2, and T3, and positive and negative affect at T1, T2, and T3. The choice of stepwise models of regression was dictated by the fact, that based on the existing body of literature it is not possible to establish the relative importance of potential predictors of the memory of pain and therefore to adopt hierarchical approach. Separate regression analyses were conducted for recalled pain intensity and recalled pain unpleasantness, independently for the PS and US groups.

3. Results

Means and standard deviations of all the study variables are presented in Table 1. The PS and US groups differed significantly in terms of age and MMSE score; the subjects in the US group were older [$t(69) = 3.97; p < 0.001$] and exhibited a lower level of cognitive functioning [$t(69) = -4.77; p < 0.001$] than those in the PS group. Therefore, age and MMSE were included in the subsequent statistical comparisons as quantitative covariates. Furthermore, since χ^2 tests revealed significant inter-group differences in gender [$\chi^2(1, N = 71) = 5.13; p < 0.05$] and type of surgery [$\chi^2(1, N = 71) = 22.5; p < 0.001$], these variables were included as qualitative factors in the subsequent ANCOVAs. None of the control variables (age, MMSE, gender, type of surgery) showed significant interactions with the dependent variables (time of rating pain intensity and unpleasantness; see Table 2); thus, they were ignored in the final analyses and interpretation of the results. As the age of the US group ($r = -0.39; p < 0.05$; $r = -0.39; p < 0.05$) and the MMSE of the PS group ($r = 0.41; p < 0.01$; $r = 0.54; p < 0.001$) were significantly correlated with recalled pain intensity and

unpleasantness, respectively, these variables were included in the subsequent regression analyses. The purpose of conducting the ANCOVAs was to rule out the collateral factors that could have generated the differences between the groups other than those due to the surgery context. Whereas regression analyses set out to identify which factors could have affected the obtained results, therefore, we also included those predictor variables that were the same in both groups.

3.1. Memory of pain

ANCOVA on pain intensity revealed no statistically significant interaction between time of rating and the context of surgery (see Table, Supplemental Digital Content 1, which presents the results of ANCOVAs for experienced and recalled pain intensity and unpleasantness). Planned comparisons of recalled versus experienced pain intensity failed to reach significance as well, indicating that participants in both planned [$F(1,65) = 0.58$; $p > 0.05$; $\eta^2 < 0.01$] and unplanned [$F(1,65) = 0.09$; $p > 0.05$; $\eta^2 < 0.01$] surgery context remembered their actual postoperative pain intensity accurately after a 3-month delay.

No significant interaction between time of rating and context of surgery was revealed by ANCOVA for pain unpleasantness (see Table, Supplemental Digital Content 1). Postoperative pain unpleasantness appeared to be remembered accurately after 3 months, regardless of whether the surgery was planned [$F(1,65) = 1.07$; $p > 0.05$; $\eta^2 = 0.02$] or unplanned [$F(1,65) = 1.46$; $p > 0.05$; $\eta^2 = 0.02$], as planned comparisons of recalled versus experienced pain unpleasantness also failed to reveal a statistically significant difference between the groups.

Overall, the results indicate that memory of postoperative pain intensity and unpleasantness was accurate, regardless of context of surgery (Fig. 1).

3.2. Mood congruence

ANCOVA revealed a statistically significant main effect of context of surgery on positive affect [$F(1,65) = 10.75$; $p < 0.01$; $\eta^2 = 0.14$; $power = 0.92$], but no interaction between time

of rating and context of surgery (see Table, Supplemental Digital Content 1, which presents the results of ANCOVAs for positive and negative affect at T2 and T3), indicating that participants in the PS group experienced greater positive affect than those in the US group at both times when the ratings were collected – i.e., T2 and T3. Subsequent planned comparisons between positive affect experienced at T2 and T3 revealed no statistically significant differences in either the PS group [$F(1,65) = 1.78$; $p > 0.05$; $\eta^2 = 0.03$] or the US group [$F(1,65) = 3.34$; $p > 0.05$; $\eta^2 = 0.05$], indicating that the positive affect experienced after surgery was congruent with the positive affect experienced 3 months after surgery.

The final ANCOVA on negative affect found no statistically significant interaction between time of rating and context of surgery (see Table, Supplemental Digital Content 1). Planned comparisons between the negative affect experienced at T2 and T3 revealed no statistically significant differences in either of the groups, indicating congruence between the negative affect experienced after the surgery and the negative affect experienced 3 months after surgery, in both planned [$F(1,65) = 1.06$; $p > 0.05$; $\eta^2 = 0.02$] and unplanned [$F(1,65) = 0.84$; $p > 0.05$; $\eta^2 = 0.01$] surgery contexts.

In summary, these results suggest that both positive and negative affect were congruent between the time after surgery and the time of pain recall 3 months later, regardless of context of surgery. Moreover, participants undergoing planned surgery reported more positive mood on both occasions, compared to unplanned surgery (Fig. 2).

3.3. Predictors of pain recall

The first stepwise, forward multiple regression was conducted to test the degree to which recalled pain intensity in the PS group was predicted by the MMSE, expected pain intensity, pain intensity experienced at T1, T2, and T3, anxiety at T1, T2, and T3 and positive and negative affect at T1, T2, and T3. Pain intensity at T2 ($\beta = 0.37$; $p < 0.01$) and MMSE ($\beta = 0.36$; $p < 0.01$) were the only significant predictors of recalled pain intensity. All the final 6th

step variables accounted for 37% of its variance (cor. $R^2 = 0.37$; $p < 0.001$; $power = 0.93$; see Table, Supplemental Digital Content 2, which illustrates all steps of the regression analysis for pain intensity in PS context).

The second regression analysis was performed to determine the degree to which recalled pain intensity in the US group was predicted by age, expected pain intensity, pain intensity at T1, T2, and T3, anxiety at T1, T2, and T3, and positive and negative affect at T1, T2, and T3. The regression was resolved at the 9th step, in which age ($\beta = -0.54$; $p < 0.001$), anxiety at T1 ($\beta = 0.57$; $p < 0.01$), negative affect at T2 ($\beta = -0.5$; $p < 0.05$), and positive affect at T3 ($\beta = 0.33$; $p < 0.05$) were significant predictors of recalled pain intensity. All the variables included in the final step explained 52% of the variance in recalled pain intensity (cor. $R^2 = 0.52$; $p < 0.001$; $power = 0.94$; see Table, Supplemental Digital Content 3, which illustrates all steps of the regression analysis for pain intensity in US context).

The third regression analysis conducted for recalled pain unpleasantness in the PS group, examined the ability of the MMSE, expected pain unpleasantness, pain unpleasantness experienced at T1, T2, and T3, anxiety at T1, T2, and T3 and positive and negative affect at T1, T2, and T3, to predict the dependent variable. In the last, 7th step, pain unpleasantness at T2 ($\beta = 0.45$; $p < 0.001$), MMSE ($\beta = 0.45$; $p < 0.001$), positive affect at T1 ($\beta = -0.29$; $p < 0.05$), and negative affect at T3 ($\beta = 0.2$; $p < 0.05$) were significant predictors of recalled pain unpleasantness. Overall, the variables at the 7th step accounted for 59% of the total variance in recalled pain unpleasantness (cor. $R^2 = 0.59$; $p < 0.001$; $power = 0.99$; see Table, Supplemental Digital Content 4, which illustrates all steps of the regression analysis for pain unpleasantness in PS context).

The final regression analysis tested the ability of age, expected pain unpleasantness, pain unpleasantness at T1, T2, and T3, anxiety at T1, T2, and T3 and positive and negative affect at T1, T2, and T3, to predict recalled pain unpleasantness in the US group. This analysis,

which was resolved in the 4th step, at which point age ($\beta = -0.46$; $p < 0.01$), anxiety at T1 ($\beta = 0.67$; $p < 0.001$), and negative affect at T2 ($\beta = -0.32$; $p < 0.05$) were significant predictors of the dependent variable. All the final step variables accounted for 47% of the total variance in recalled pain unpleasantness (cor. $R^2 = 0.47$; $p < 0.001$; $power = 0.97$; see Table, Supplemental Digital Content 5, which illustrates all steps of the regression analysis for pain unpleasantness in US context).

In sum, recalled pain intensity was best predicted by pain intensity after surgery and MMSE score in planned surgery context, whereas in unplanned surgery context it was predicted by age, anxiety before surgery, negative affect after surgery and positive affect at recall. The significant predictors of recalled pain unpleasantness included pain unpleasantness after surgery, MMSE score, positive affect before surgery and negative affect at recall in planned surgery context; in unplanned surgery context, the significant predictors were age, anxiety before surgery and negative affect after surgery.

4. Discussion

4.1. Accuracy of pain recall

One of the most important findings to emerge from this study is that memory of postoperative pain is accurate after a 3-month delay, which is in line with previous studies reporting correct recall of postoperative pain after 1 or 2 days¹³ and 4 to 6 weeks,^{18,19} and pain resulting from other invasive medical procedures after delays ranging from one week to 6 months.^{6,10,17,39} The present study extends these findings to long-term memory of a novel type of pain related to orthopedic surgery. Furthermore, the statistical analyses, which controlled for age, gender, level of cognitive functioning, and type of surgery, revealed no significant differences between experienced and recalled pain, regardless of the operation's context. The above findings seem to contradict the study by Babel et al.,⁶ which suggested that the context of a painful event may have a differential effect on its memory. Despite the presumed positive

framing of elective hip surgery (partly supported by higher positive affect experienced by these patients) and the negative framing of trauma hip surgery,²⁸ no over- or underestimation effects were observed in this study. The lack of support for this hypothesis could be contributed to small effect sizes and relatively low statistical power reported in this study. However, it might also stem from several differences between the two studies; namely, the different types of pain (orthopedic vs. gynecological), the gender of the study participants (male and female vs. female only) or the age groups studied (older vs. middle age adults). Among the plausible explanations for why these effects do not generalize to memory of pain related to orthopedic surgery is that even a desired operation still remains a painful surgical procedure that violates the physical integrity of a patient. Moreover, the benefits of hip surgery are not immediate, therefore, the characteristics of this experience may be insufficient to observe underestimation of pain recall.

4.2. Mood congruence

The examination of mood congruence revealed that both positive and negative affective states did not differ in the postoperative and recall phases, in either of the study's groups. It should be noted that the effect was found to be small and the present study might not have been sufficiently powered to detect such difference. Nevertheless, combined with the accuracy of pain recall, these results may suggest that mood dependent memory²⁶ applies to memory of pain also, which further emphasizes the contribution of affective variables in forming and retrieving pain memories. Teasdale and collaborators were probably the first to observe that events accompanied by positive affect are better recalled in the same, positive mood, and that negative emotions likewise facilitate memory.⁴⁰⁻⁴² Mood congruence between the contexts of encoding and retrieving particular events, which has been demonstrated to increase the probability of accurate recall, is known in the literature as the mood dependence effect.²⁶ With regard to pain, it appears that individuals who report similar mood states at the

time of a painful experience and at the time of its recall, are more likely to remember the pain accurately, which may partly account for correct pain recall among orthopedic surgical patients. These findings seem to be in agreement with the network model describing affect as a node in a memory network associated with a particular event, which may serve as a retrieval cue in the future, as well as the integrated memory trace model, which proposes that the sensory, affective, and cognitive aspects of a given experience are combined into a single memory trace, allowing one of these aspects to serve as a retrieval cue for the others.⁴³ Therefore, the present study enhances our understanding of emotional contributions to pain memory, through the incorporation of broader research and theories of memory and affect.

4.3. Predictors of recalled pain

Finally, the present study provides evidence that despite accurate recall, remembered pain tends to be predicted by different factors, depending on the context of the painful experience. In addition, sensory and affective aspects of recalled pain may rely on somewhat different variables. Surprisingly, it is not common to examine both dimensions of pain in pain memory studies (see^{1-3,18}). The present findings, therefore, support the claim that even though they may be highly correlated, pain intensity and unpleasantness are separate, independent aspects of pain,^{44,45} which is also apparent in their memories.

4.3.1. Age and cognitive functioning

The current findings highlight the differential contributions of age and level of cognitive functioning to the memory of pain, reflecting the uniqueness of the group of older individuals, which is rarely studied in this field of research. Age appears to be a strong, negative predictor of recalled pain intensity ($\beta = -0.54$) and unpleasantness ($\beta = -0.46$) among patients undergoing trauma hip surgery, indicating that individuals remember less pain than initially experienced with increasing age. In contrast, the only other study to investigate pain memory among the older adults found that age was not associated with the accuracy of recalled cardiac

pain.⁸ However, research on children and middle-aged adults provides inconsistent results, reporting both the presence^{9,46–49} and absence^{39,49–52} of age effects on pain memory. To date, age effects regarding the amount of reported clinical pain are inconclusive; however, there is some evidence indicating there is an elevated threshold for experimental pain in older age groups.²⁹ The present results suggest that similar changes may be reflected in pain memory. It can be argued that MMSE score, on the other hand, is a strong, positive predictor of remembered pain intensity ($\beta = 0.36$) and unpleasantness ($\beta = 0.45$) among individuals undergoing elective hip surgery, which suggests higher levels of cognitive functioning are associated with recalling more pain than was initially experienced. With regard to the evidence of reporting less intense and unpleasant pain by people suffering from dementia, compared to healthy individuals,³¹ current findings support the notion that cognitive decline can also influence pain memory. Nevertheless, generalizability of these findings is limited to individuals with mild cognitive impairment, as those with moderate and severe impairment were not included in the present study. Although this paper significantly contributes to a very limited literature about the nature and the factors influencing memory of pain in older adults, future research should attempt to overcome the limitations of self-report measures in that population and extend this knowledge to people suffering from more severe cognitive impairment.

4.3.2. Experienced pain

The results of this investigation revealed that initially reported postoperative pain is a strong, positive predictor of recalled pain intensity ($\beta = 0.37$) and unpleasantness ($\beta = 0.45$), however, only among patients undergoing planned surgery. This suggests that episodic memory of pain is substantially influenced by the actual pain experience. Comparable effects also have been observed for pain resulting from gynecological surgery, running a marathon, migraine headaches, dental procedures, and experimental stimulation.^{6,9,11,15,21} In accordance

with Gedney and Logan's model of acute pain recall,²¹ the memory of pain after a 3-month delay primarily depends on the initially reported pain; however, the variance in pain recall is already shared with the negative affect accompanying the painful event and the contribution of negative affect increases with longer delays. The authors argue that the memory of actual pain fades with time, and that negative affect provides cues for its reconstruction.

4.3.3. Negative affect

Indeed, negative affect appears also to be a good predictor of pain memory, with the exception of recalled pain intensity after planned surgery. For the patients who underwent trauma hip surgery, it was their emotional state in the postoperative period that predicted their remembered pain intensity ($\beta = -0.5$) and unpleasantness ($\beta = -0.32$). In the case of elective surgery, on the other hand, negative affect at the time of recall was a significant predictor of recalled pain unpleasantness ($\beta = 0.26$). Several previous studies have reported that negative emotions felt at various time points influence the recall of pain intensity and/or unpleasantness,^{6,9,11,15,21} supporting the model proposed by Gedney and Logan.²¹ The current findings are in line with the memory network model as well.⁴³

4.3.4. Anxiety

Existing research has demonstrated that anxiety, as a specific form of negative affect, makes a significant contribution to pain memory,^{6,9,12,14–16} thus, it was treated as a separate, independent factor in the present study. As a matter of fact, state anxiety reported before surgery was found to be the strongest positive predictor of recalled pain intensity ($\beta = 0.57$) and unpleasantness ($\beta = 0.67$) in the context of unplanned surgery. From an evolutionary perspective, anxiety may facilitate the memory of painful events, so that is easier to avoid similar experiences in the future. Interestingly, the influence of anxiety on recalled pain was observed only among patients with hip fractures, and not for those awaiting elective surgery,

which was a desired event and therefore did not have informative value about a threat to be avoided.

4.3.5. Positive affect

The research to date has tended to focus on negative rather than positive emotions in relation to pain. The few studies that have investigated positive affect have provided ambiguous results, reporting that it was^{6,12,15,16} and was not¹¹ a significant predictor of remembered pain. The current study offers some noteworthy contributions to the existing body of research by demonstrating an influence of positive affective state on pain memory. In particular, positive emotions felt before the surgery significantly predicted remembered pain unpleasantness in the context of a planned operation ($\beta = 0.29$), which might be due to the positive framing of the awaited hip replacement, whereas positive affect at recall contributed to the memory of pain intensity among patients after an unplanned surgery ($\beta = 0.33$). These findings, in conjunction with those regarding negative emotions, highlight the importance of considering affective state at the time of recall as a possible factor influencing pain memory.

4.4. Conclusions

The present study revealed that a variety of factors influence pain memory, depending on the context of painful experience and the aspect of pain that is being recalled. Planned surgery appears to be associated mostly with experiential predictors of remembered pain, with additional emotional factors explaining recalled pain unpleasantness, whereas memory of pain after unplanned surgery seems to depend not on the actual sensory experience, but on affective factors (especially anxiety) in both dimensions of recalled pain, possibly due to the largely negative valence of acute trauma. To recapitulate, it can be argued that the actual intensity and unpleasantness of experienced pain substantially contribute to its memory, just as do positive and negative affective states preceding and accompanying painful events, as well as those present at the moment of recall. However, despite high statistical power of the

conducted analysis, it should be noted that the above factors are only able to explain approximately half of the variance in pain memory, which means that additional research on other factors is needed to increase the prediction of pain recall. In addition, this study demonstrated that the memory of pain associated with orthopedic surgery remained accurate after 3 months, which may be partly attributable to mood dependent memory. Nevertheless, further research involving the manipulation of affect congruence is required to establish the extent to which mood dependence explains the accuracy of pain recall, as the present study only provides speculative interpretation on that matter.

Several limitations of this study need to be considered. It should be noted that pain located at the hip joint tends to increase with movement, whereas it can be less afflicting at rest. Therefore, generalization of such postoperative orthopedic pain to other types of acute pain should be made with caution. Moreover, it is possible that pain experienced between discharge and recall phase could have interfered with recalled pain ratings. After a hip surgery, it is a standard practice to prescribe rehabilitation that can be associated with additional pain, however, it was not verified whether the participants underwent any physiotherapy. Nevertheless, the two groups of patients did not differ in terms of pain experienced during the recall phase, nor was it a significant predictor of recalled pain ratings. Thus, at least the pain experienced at recall should have not interfered with the accuracy of pain memory. Yet another limitation of the present work is that despite using the same measures in all stages of the study, the third phase was conducted via telephone, which might have influenced the fidelity of the results. Although no distortions in pain memory were observed in this study, the possibility that they would occur with a delay longer than 3 months, or that present study did not have sufficient power to detect them, cannot be ignored. It should be noted that due to limited availability of older orthopedic patients undergoing specifically hip surgery, the sample size is relatively small and statistical power of performed

analyses is low, in addition to small effect sized (see Table, Supplemental Digital Content 1, which includes effect sizes and power calculations for main effects and interactions). Notwithstanding, the results shall be considered valuable in the context of clinical research, where ecological validity of the findings is a crucial aspect.

Despite certain limitations, this study makes several noteworthy contributions to the current research literature. To date, the long-term memory of postoperative pain has been investigated in the context of vascular, dental, gynecological, and oncological surgeries, and this study is the first to focus on orthopedics, specifically, hip replacement surgery. The study also bridges a gap in the research, as studies on pain memory among the older adults have rarely been conducted, perhaps due to considerable difficulty in recruiting subjects from this age group. Importantly, age was identified as one of the factors affecting pain memory, thus stressing the need to consider unique characteristics of older adults in this field of research. Moreover, this is one of few studies to verify the influence of positive affect on pain memory, and the only one to examine the mood dependence effect on the memory of painful events. Although the vast majority of reports in this field have been limited to remembered intensity of pain, the current study also explored another crucial aspect of pain – that is, pain unpleasantness.

The present findings highlight the significance of monitoring the psychological state and well-being of patients in the perioperative period, since these factors determine how such painful experiences will be remembered, and can be easily managed with simple interventions aimed at reducing anxiety, affect enhancement, and adequate pain control. The fact that older patients keep accurate memories of pain, may have significant ramifications for engaging in rehabilitation, but also in activities related to risk of falls. It is recommended that future studies in the field of pain memory are conducted within a prospective model, with detailed assessment of pre- and postoperative factors influencing present and retrospective pain

reports, and follow-ups on patients' condition after a certain time. The influence of age and level of cognitive functioning should be acknowledged not only in geriatric care, but also in scientific research involving older age groups.

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Figure legends

Fig. 1. Accuracy of pain recall. NRS (Numeric Rating Scale) mean ratings of experienced and recalled postoperative pain intensity (on the left of the bar chart) and unpleasantness (on the right of the bar chart) in the two study groups. There were no significant differences between recalled and experienced pain intensity or unpleasantness, either among patients undergoing planned surgery (PS) or those undergoing unplanned surgery (US). Error bars represent 95% confidence intervals.

Fig. 2. Mood congruence. PANAS (Positive and Negative Affect Schedule) mean ratings of the positive affect (on the left of the bar chart) and negative affect (on the right of the bar chart) experienced after the surgery (T2) and at the time of recall, after a 3-months delay (T3), in the two study groups. There were no significant differences between positive affect or negative affect reported at those two time points, either among patients undergoing planned surgery (PS) or those undergoing unplanned surgery (US). Error bars represent 95% confidence intervals.

List of Supplemental Digital Content

- Supplemental Digital Content 1. Table which presents the results of ANCOVAs for experienced and recalled pain intensity and unpleasantness, and for positive and negative affect at T2 and T3. doc
- Supplemental Digital Content 2. Table which illustrates all steps of the regression analysis for pain intensity in PS context. doc
- Supplemental Digital Content 3. Table which illustrates all steps of the regression analysis for pain intensity in US context. doc
- Supplemental Digital Content 4. Table which illustrates all steps of the regression analysis for pain unpleasantness in PS context. doc
- Supplemental Digital Content 5. Table which illustrates all steps of the regression analysis for pain unpleasantness in US context. doc